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# DISPOSAL OF INDUSTRIAL WASTES BY LAGOONING

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## ABSTRACT

Lagoons for industrial wastes have developed out of simple holding pits to contain solids and remove water by evaporation, infiltration, or overflow. The eventual failure of such lagoons has led to more sophisticated management of various types. Lagoons are used to provide one or more of the following treatments: 1) mixing and equalization of loads, 2) clarification and retention of solids, 3) dewatering, 4) chemical neutralization or conversion, and 5) removal of biologically active materials. Each of these functions is discussed with emphasis on the ultimate fate of the materials that have been placed into the lagoon.

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Lagoons have been used from the earliest days to dispose of industrial wastes. Various names occur in the literature including basin, impoundment, mud lake, pond and pool. The use of a hole in the ground to receive unwanted liquids originated with primitive cesspits and even today many industrial wastes receive a treatment that is no more sophisticated. Perhaps because of the antiquity of the process, the literature on lagooning of industrial wastes is sparse and there are very few papers that deal primarily with industrial lagoons. Most of the references in the literature are of the type: "The lagoon originally built to receive the wastes had filled up (or otherwise failed to function) much sooner than had been anticipated and the following steps were taken to replace it."

Lagoons are used to provide one or more of the following treatments: mixing and equalization of loads, sedimentation and clarification, retention of solids, dewatering, chemical neutralization or conversion and removal of biologically active materials. Dewatering includes evaporation and infiltration as well as decantation of clarified supernatant. Originally industrial lagoons were simply used as a place to put unwanted liquids and solids and little or no thought was given to treatment. Water either drained out into the ground waters, or the bottom became impermeable and some overflow was necessary. Sooner or later as the industry grew the lagoon filled up with solids or became a nuisance if it was overloaded with putrescible organic matter. The problem of disposing of the wet and sometimes putrid solids was rarely faced in advance. Many lagoons were designed to hold everything for a number of years with the hope that when they filled up someone else

would have the problem. A "permanent" lagoon that is full of a soft sludge is a permanent problem and represents a liability since it must be fenced to keep the public out. It also ties up valuable real estate. If a sludge filled lagoon is above grade, it may become a hazard if the dikes break allowing the contents to flow over the countryside. Proper management of lagoons, therefore, includes consideration of the ultimate disposal of the contents and is based on the functions that lagoons can best furnish.

By far the commonest function of lagoons for industrial waste is dewatering. Solids will settle to the bottom and oils and greases will float to the top where they can be skimmed off. The aqueous effluent may be discharged to surface waters, it may percolate into the ground, or it may evaporate. In continuously discharging lagoons sedimentation tends to occur at the sides where flow rates are least and further reduces the flow in these areas. The final result is a channel that meanders through the middle, short circuiting most of the area and discharging untreated wastes unless solids are removed regularly. Overflow weirs must be designed as in any other type of clarifier to prevent high local velocities that carry suspended solids into the overflow.

Sedimentation lagoons may be operated with intermittent discharge of water. For example, wastes may be held during low flow of a river and discharged during annual floods. This is a popular method for disposing of salt brines. Sometimes a permanent lagoon appears to have been constructed so that it would be "accidentally" washed out. In one case a lagoon to hold acidic wastes was built near a river. An iron pipe carrying water under high pressure was buried in the dike. The pipe, of

course, corroded after a few years and the high pressure water washed out the dike releasing the acid wastes and killing many fish.

Lagoons may also be used to hold wastes until the dry season when the water can be decanted and the solids dried. The usual reason for intermittent discharge from lagoons is, of course, the convenience of the operator. However, wastes that might be acceptable in sanitary sewers if they were discharged continuously are intolerable if they are concentrated in a lagoon and discharged all at once. An example is the aluminum hydroxide floc from water clarification. Studies at Cincinnati have shown that this floc does not upset biological treatment if it is fed at the rate it is produced in water clarification and it can actually increase the removal of phosphates. However, the common practice of holding these wastes in a lagoon to dewater, then flushing them out after several months naturally causes upsets in any treatment plant.

Dewatering, as stated earlier, can occur in three ways. Evaporation to the atmosphere is usually only useful to dry solids after decantation although total evaporation lagoons are used in arid climates to receive brines and other wastes. Decantation of clarified water may still cause pollution if the water contains dissolved materials and it may be necessary to provide further treatment for these effluents. Infiltration of water containing dissolved salts can seriously pollute ground water and in many areas lagoons are required to have impermeable linings to prevent infiltration. Phosphates, salts of heavy metals and organic matter are usually strongly adsorbed on soil minerals and rarely cause pollution of ground water. However, sodium salts of chlorides, chromates, sulfates are serious pollutants since they move nearly as fast as the ground water itself.

Nitrates which may be formed by biological oxidation of ammonia and organic wastes are serious ground water pollutants. Suspended colloids such as aluminum and iron hydroxides and clay as well as biological colloids usually clog infiltration media very rapidly and prevent useful infiltration, however they can rarely be relied upon to seal the bottom of a lagoon against unwanted infiltration.

Dewatering of colloidal sludges is greatly accelerated by freezing. Perhaps the most favorable case is that of aluminum hydroxide sludge which without freezing settles to a gel containing no more than 10% solids. When frozen this gel dewaters to a sand that settles rapidly. In Copenhagen aluminum hydroxide sludge is spread in thin layers in lagoons to take advantage of even mild frosts. After each thaw the supernatant water is drained off. A layer of alumina has been allowed to accumulate on the bottom for several years without interfering with the operation of the lagoon. Freezing is also effective for dewatering iron hydroxide and biological sludges although to a lesser degree than in the case of aluminum hydroxide. It is important to freeze in thin layers since deep lagoons will not freeze to the bottom and relatively little is gained from partial freezing.

Eventually, of course, lagoons will fill up and the settled solids will have to be removed. In dry climates lagoons may be drawn down and dried out and the solids removed each year. Such lagoons should be designed to permit standard earth moving equipment to come in to remove the solids. When solids are removed they may be used as land fill, in which case it is important that they be sufficiently compact to bear a load. Alternatively, the wet solids can be applied to the land and assimilated into the soil.

The decomposition of organic matter and the preservation of soil porosity is greatly facilitated by aerobic conditions. Soil bacteria have tremendous capabilities for oxidizing organic substances. Even hydrocarbon wastes are rapidly destroyed when applied to well plowed soil. At one refinery in Texas the soil treated a 15 cm thick layer of refinery wastes in 6 to 9 months to the extent that the soil is ready for another layer of oil. To accomplish this treatment the soil is repeatedly turned by earth moving equipment and, of course, no higher plants grow in the plowed field while the oil is being oxidized.

Heavy semi-solid sludges are expensive to handle even with modern earth moving equipment. It is frequently easier to resuspend solids with a jet of water and flush them away. Pipeline or truck transport of wet sludges followed by spraying or flowing them onto the land reduces handling costs and takes advantage of natural dewatering on the earth. This method of disposing of lagooned solids is particularly useful in the food manufacturing industries but can be used for clay pigments from paper making and other oxide wastes. Ideally one would transport the sludge before it is so compact that it must be resuspended in water.

Lagoons may be used for chemical treatment of wastes. For example, acids from one part of a process can be neutralized by bases which may come at another time. Frequently neutralization produces a sludge which settles out and further purifies the effluent. An important function of lagoons is thus to equalize the flow and strength of wastes to facilitate further treatment. They also provide time for slow reactions such as the precipitation of calcium salts. Oxidation of Fe II to Fe III by the air is another

chemical treatment that is useful for mine wastes as well as steel mill liquors. Reduction of chromates to chromic hydroxide and nitrates to nitrogen gas in anaerobic lagoons can be considered a form of chemical treatment. Likewise, $H_2S$ produced in anaerobic lagoons from sulfates and organic matter could be used to precipitate heavy metals as their sulfides.

Biological treatment of industrial wastes in lagoons is limited to organic wastes and the function of the lagoon is primarily to remove BOD. Wastes from the food processing industries by nature resemble human wastes although the ratios of carbon to nitrogen to phosphorus will differ for each waste. Pulp and paper wastes are usually deficient in both N and P although paper coatings may provide either or both of these essential nutrients. Petrochemical and coal processing wastes usually require additions of both nutrients for satisfactory biological treatment.

The ordinary lagoon when loaded with BOD goes anaerobic. As such it resembles an unagitated digester and will usually produce bad odors. Sludge which settles to the bottom may be buoyed up by gas causing some stirring of the contents. In favorable cases a dry crust may form on the top retaining the odors and permitting unobjectionable operation. Certain animal wastes have been successfully treated in this way. An anaerobic lagoon, like a digester, reduces the volume of solids and stabilizes those that remain so that they can be dried and hauled away. It likewise produces an effluent that is high in BOD and usually requires further aerobic treatment before discharge. Objectionable odors from anaerobic lagoons are sometimes reduced by treatment with nitrates which prevent sulfate reduction so long as they are present.

Aerobic lagoons for industrial wastes are an extension of other biological treatment methods and differ little from lagoons for domestic sewage. Aeration may be by diffusion from the air or from algal growth but it is frequently necessary to use forced aeration as in a Pasveer ditch, from surface aerators or submerged perforated air hose. The objective is reduction of BOD in the effluent, and management is essentially the same as for municipal wastes. Loadings averaging 130 kg BOD/Hectare, day have been successfully treated in aerobic lagoons and substantially higher loadings are occasionally reported.

Facultative lagoons conbining both anaerobic and aerobic treatment are the most versatile and, in fact, many aerobic lagoons have an anaerobic bottom sludge. Photosynthesis by algae is the principal source of dissolved oxygen since aerators would mix the contents and destroy the anaerobic action. A series of lagoons in which the first are anaerobic and the latter are aerobic can provide a high quality effluent if properly managed. A preliminary aerobic step may be desirable to remove poisons such as cyanides or to prevent shock loading when wastes are discharged intermittently.

The only industrial wastes which cannot be treated by lagooning are those containing volatile poisons, such as free HCN, and radioactive isotopes. Low level radioactivity in an isolated cooling water lagoon has caused trouble when wild ducks fed in it and picked up radioactivity from plants growing in the contaminated water. In this case it was necessary to kill the birds so that they would not be dangerous to hunters who might shoot them later in their migration. Steam from cooling water lagoons could conceiv-

ably cause dangerous fog if located close to public highways. Water soluble toxic wastes should not be disposed of in lagoons that overflow to surface waters or percolate into ground waters unless there is adequate treatment in the lagoon. Almost any other sludge can be economically disposed of in a lagoon if the quantity is small enough but many sludges can be treated more economically in other ways particularly if the volumes are large.

If a sludge is to be treated in a lagoon by biological action it must of course be free from poisons and should contain an adequate concentration of nutrients. A test for biological treatability using appropriate anaerobic or aerobic seed sludges should be run to check qualitatively for biological response. It is apparently not possible to reproduce lagoon conditions in the laboratory closely enough to calculate the required dimensions for biological treatment and estimates must be based on similar installations. Well stirred aerated lagoons may be an exception in that reasonably good estimates of power requirements for oxygenation can be calculated from the BOD loading and oxygen transfer factors. Likewise sludges that settle poorly, such as aluminum hydroxide, do not thicken as well in a lagoon as in a test cylinder. Therefore, although hydraulic dimensions can be calculated, the capacity for solids must be estimated with a large safety factor. Indeed most lagoons for industrial wastes have proven to be too small either from miscalculation of capacity or from inadequate estimates of future growth.

Conclusion: Lagoons are devices for treating wastes. As such they should be operated properly with an understanding of the various functions they perform and the ways in which they can be damaged. An unmanaged lagoon sooner or later will become a liability rather than an asset.